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COMPUTER IMPLEMENTED CLASSIFICATION OF VEGETATION USING AIRCRAFT ACQUIRED MULTISPECTRAL SCANNER DATA

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ABSTRACT

The use of aircraft 24-channel multispectral scanner data in conjunction with computer processing techniques to obtain an automated classification of plant species associations will be discussed. The classification of various plant species associations will be related to information needed for specific applications.

In addition, the necessity of multiple selection of training fields for a single class in situations where the study area consists of highly irregular terrain will be detailed. A single classification will be illuminated differently, in different areas, resulting in the existence of multiple spectral signatures for a given class. These different signatures result since different qualities of radiation upwell to the detector from portions that have differing qualities of incident radiation. Techniques of training field selection will be outlined, and a classification obtained from a natural area in Tishomingo State Park in northern Mississippi will be presented.

INTRODUCTION

From earliest times man has chosen to settle in the vegetated regions of the earth because they best provided for the needs of man. For the most part, this is still true today.

It is the radiant energy which is reflected or radiated from this vegetational cover that is monitored in the acquisition of remotely sensed data from either aircraft or spacecraft over these land areas. This plant cover can either be partially or wholly natural, such as in some of our parks and forests, or it may be plant types which exist solely as a result of man's intervention such as farmlands.

The plants that are to be found in a given area depend upon many local environmental conditions such as soil types, rainfall, frost-free period, etc. This aspect is well known to plant ecologists and agronomists alike, and is generally understood by the public. For example, one would not expect to successfully farm cotton in Alaska. Less well understood are interactions of other aspects of the ecosystem which can be determined through vegetational parameters. As an example, in the marshlands to be found along the Gulf Coast, the salt marsh moquito Aedes sollicitans breeds, and oviposits on soil that at the time of oviposition is not covered by water but is periodically inundated by tidal action within these wetlands. These sites of probable oviposition can be determined by (plant) vegetational associations as found in different hydric regimes. As these associations can be separated and classified when multispectral scanner (MSS) data is properly processed, these oviposition sites can be determined through the identification of the plant associations that are found thereon.

Table I gives a few examples of some applications of vegetational analysis, where this analysis is based on the acquisition of remotely sensed data.

The purpose of this paper is twofold. One will be to outline several criteria which must be understood and employed in training field selection where differing physical factors within the site dictate the necessity of multiple training field selection for a single class or association to be properly identified. The second purpose will be to detail several applications of inferential classifications derived from plant association analysis and to discuss several of these in some depth to better acquaint the reader with the potential of the inferential method.

RECOGNITION OF PHYSICAL FACTORS AFFECTING TRAINING FIELD SELECTIONS

Shortly after the organization of the Earth Resources Laboratory (ERL), the problem of determining the possibility of classifying marsh vegetation arose. This inquiry was the direct result of interest by local mosquito abatement districts and by various state agencies responsible for management of wetland resources. The details of mapping vegetational associations to infer high mosquito oviposition risk sites is covered elsewhere (Cibula 1972).

The coastal marshlands found in part of Louisiana and Mississippi are part of an extensive alluvial plain which is an older portion of the Mississippi Delta. This plain, which has little relief, slowly drops toward the Gulf, and is close to sea level over most of its extent.

The plants which are found in the marsh are often considerably smaller than the resolution cell obtained from scanner data. This criterium even holds for MSS data obtained from 1220m where an individual element is approximately being 2.5 X 2.5 meters (8' X 8'). As this is the case, in the marsh one often finds that an element will contain a number of individual plants--in many cases of differing species such as a mixture of *Juncus roemerianus* and *Spartina patens*. Additionally, the shadows of the plants also often fall within the element. The lack of relief in the marsh contributes to extremely uniform illumination over very extended areas. Consideration of all these factors produces integrated signatures from each element - often the element producing a signature of an associational complex. Taken in total, all the elements from a well chosen training field yield well defined statistics with relatively small divergences. In practice, the associations in the marsh often separate well from each other.

In upland areas, the situation described above often does not hold. In dissected terrains, it is not unusual to find a particular association on both sunlighted and shadowed sides of ridges. Such a situation was encountered in a study area in north Mississippi. Tishomingo State Park (Figures 1 and 2) was chosen for a low altitude 1220 meters (4000') MSS flight to determine the effect of terrain dissection on plant species association classifications. Figure 3, from an RC-8 color infrared photograph taken simultaneously with acquisition of MSS data shows the diversity of illumination types to be found. This mission, one of a series planned over this area at differing seasons, was flown in January. The primary purpose of this study was to determine the efficiency of processing MSS data obtained in the winter season to separate pine from hardwood. The application to rapid, large area forest inventory is obvious.

Since it was recognized that illumination on pine, hardwood, etc. when on the shadowed side of a ridge differed in both quantity and quality from these same associations on a sunlighted slope, multiple training fields were taken of each association. These separate training fields for each class under differing illumination conditions were treated as separate classes during classification, but were color coded the same color when the display was prepared. The result of several classifications over a restricted area is shown in Table II. As a comparison, this same area was photo interpreted and a random dot pattern was used to produce the acreage calculations. From these acreages for each class, the percentages of the total acreage for that class were calculated. For the MSS classifications, a program to compile acreages for each class was used.

Two obvious discrepancies are obvious in MSS classification I. The percentages classified for water and for pine were low. Inspection of the classified product showed that the error in water classification resulted as much of the water (river, lake edges) was in partial or full shadow. Choosing additional water training fields from representative shadowed areas, minimized the problem. This is shown with classification II. (See Figure 4)

The situation with pine was somewhat different. From the table, it is evident that the difference between the classified pine and the pine which should be classified shows up primarily in the classified category.

Field studies in areas of high disjuncture for pine classification revealed that the pines which are unclassified are primarily individual pines scattered among hardwoods -- a common feature of the Oak-Pine forest region (Braun, 1950).

Further field analysis of these situations revealed that many of these pine were open crowned. Coupled with this, as the mission was flown at a time of year when the sun angle is low, the shadow of the crown fell off to one side, well away from the base of the tree. This meant that the understory beneath the pine was sunlighted as the neighboring deciduous trees were leafless. As a result of both the open crowned aspect of these trees, and the illumination of the forest floor beneath these crowns, the spectral signature seen by the scanner was a composite of the signature from the pine and that of the forest floor, yielding a signature different from any of the chosen classes. Hence, these pines recorded as unclassified.

To rememdy this situation, it was necessary to select very small training fields from over a number of these individuals, such that there would result a sufficient number of elements to produce reliable statistics. This has been accomplished, and will be reported in the future.

INFERENTIAL CLASSIFICATIONS

Xeric vs. Mesophytic sites: Longleaf pine (*pinus palustris*) is commonly found along the coastal plain in the southeast. Generally, this pine is found growing on soils which characteristically are low in organic matter (Fowells, 1965). Within these constraints, on sandy, well drained and therefore xeric sites, turkey oak, blue-jack oak, sand post oak and saw palmetto are found. On moister, and therefore more mesophytic sites, dogwood is one of the common understory components with longleaf. Classification and identification of these understory components, also allow the identification and location of these two differing site types.

Fusiform Risk Zones: Fusiform rust (*Cronartium fusiforme*) an important fungal pathogen to pines in the south, cannot be transmitted from pine to pine. This fungus requires an alternate host to complete its complex life cycle.

Aeciospores produced by this fungus in infected pine, are released in the spring. These spores are carried by wind and air currents to oaks, where they germinate on the leaves (Czabator, 1971). About 20 to 35 days after germination of the aeciospore on the oak leaf, the fungus produces telia on the lower surface of the oak leaf. The telia produce teliospores which soon germinate to produce sporidia. It is the sporidia which carry the infection from the oak to the pine. The sporidia are very sensitive to adverse conditions and quickly lose their capacity to initiate an infection. As a result, the maximum distance they can travel from an oak to infect a pine is not great.

An ERL project is currently in progress in cooperation with personnel from the Gulfport station of the Southern Experiment Station, USFS. Personnel at the Gulfport Field Station are engaged in research to quantify the distance relationship between oak and pine to the probability of sporidial infection. Analysis of aircraft MSS data is in progress at ERL. At this writing, it has been demonstrated that oak can be separated and classified from other forest species (See Figure 5). The classification of oak will be used to generate a map which will relate a particular area to the probability of infection if pine is planted on that site.

RECOGNITION OF STRESS AND STRESS RELATED PARAMETERS

Plants under stress exhibit spectral signatures which are different from the signature of these same species which are not stressed (Weber & Polcyn, 1972). Stress due to disease is what most often comes to mind when one considers a situation where a plant may be stressed.

In this paper, I present another aspect of stress--that due to mycorrhizal insufficiency and how remote sensing can be used to identify these stressed areas. The mycorrhizal relationship is one of a symbiotic relationship in which the smallest order of secondary roots of a tree are invaded by specific fungi during periods of active root growth (Hacskaylo, 1972). Without mycorrhizae, many plants (including especially important forest species) could not survive in the high competitive biological communities found in natural soil habitats.

With reference to Southern Pine, this relationship is dramatically shown by studies of Vozzo (1971). In this study, slash pine were grown in a situation where the mycorrhizal relationship was not allowed to be established. This is shown in Figure 6.

At the same time, a second group of slash pine were inoculated with mycorrhizal fungi during the second year of growth. At the end of a 5-year period, the growth of these inoculated trees in shown diagrammatically in Figure 7. These two extremes show the marked benefit of this relationship for southern pine. In a competitive environment, the pine in which this relationship was not at all established would not be able to compete and as such would not survive. Under natural conditions, mycorrhizae are usually found within all forest areas, but the degree of involvement shown with respect to the quantity and speciation varies greatly.

Where this relationship is developed to the maximal extent, we have maximal growth of pine, where this relationship is minimal, we have poor growth and a condition of increased stress with these pines.

The reason for this stressed condition in areas of low mycorrhizal incidence is that the fungal partner in this relationship where established, assists the trees in nutrient update, increases solubility of minerals from soils that are necessary for trees, helps to protect roots against pathogens, moves carbohydrates from one plant to another, produces plant growth hormones and by the coupling of the mycelial network of the fungus to the tree roots, one finds a greatly increased surface area available for water uptake (Hacskaylo, 1972). This is especially important in times of drought.

If areas could be found where there exist differing degrees of mycorrhizal involvement, it would then be possible to select these areas as training fields for possible separation by the use of the technique of computer automated classification of multispectral data. These separations would, of course, be based on the presently assumed differences in spectral signature resulting from the differences in the degree of mycorrhizal involvement. These differences in spectral signature might well arise from differing stresses that would be found in these different areas.

Since the training fields needed would be relatively large (at 1200 meters, one would need 30 x 30 m. training fields), finding areas of such size that differ in mycorrhizal involvement would appear to be quite improbable, however, one such area was located within the Harrison Experimental Forest, north of Gulfport.

The Harrison Experimental Forest is located about 20 miles north of the Mississippi Gulf Coast (Figure 8). One of the projects currently under investigation is a fertilization study involving the three species of southern pine: slash, loblolly and longleaf pine. The area had been stocked with second growth longleaf pine before it was clear cut in 1959. The soils are upland fine sandy loams in the Bowie and Shubuta agricultural series and are low in nitrogen, phosphorus and potassium.

The slash pines were open pollinated progenies from two groups of five parents each. The loblolly pines were open pollinated progenies from one group of five parents and from a second group of two parents. For each of the pines, the two groups were distinguished on the basis of specific gravity; one group having wood of high specific gravity while the second group had trees whose wood was of average specific gravity.

For the three species, equal amounts of seed from parents within each group were mixed before sowing in a nursery. The one year old seedlings were lifted and row planted at 10 X 10 foot spacings in February and March 1960. Plots consisted of 100 trees surrounded by two rows of border trees and were arranged in four replications. The 10 treatments (the two wood density classes and five cultural treatments) were completely randomized within each replication as shown in Figure 9. The treatments given for each species and each wood density class within each species on each of the four replications are as shown on the following Table:

TABLE III. FERTILIZATION TREATMENT

1) Cultivation, no fertilization.

2) Cultivation with 100 lbs N, 50 lbs P_2O_5 and 50 lbs K_2O/acre.

3) Cultivation with 200 lbs N, 100 lbs P_2O_5 and 100 lbs K_2O/acre.

4) Cultivation with 400 lbs N, 200 lbs P_2O_5 and 200 lbs K_2O/acre.

5) No cultivation, no fertilization.

On the control plots, stumps, soil and competing vegetation were undisturbed. In the cultivated plots, the plots were disked three times each season for 3 years after planting and in the fourth and fifth seasons, the plots were mowed. On those plots which were fertilized, fertilizer was broadcast and disked into the soil at the beginning of the second season. All plots were sprayed three times with a Bordeaux mixture and DDT in both the second and third seasons. Although 14 years have elapsed since the single fertilization treatment, the high fertilization plots now still show increased growth rates when compared to the non-fertilized plots.

In an unpublished study in this same fertilization study area, John Menge demonstrated increased mycorrhizal involvement in those plots which had been fertilized. There apparently is a relationship between a single treatment of fertilizer and mycorrhizal involvement.

To examine this aspect further, as part of the overall Gulf Coast MSS forestry investigations, a program was initiated to determine the differences in mycorrhizal sporophore counts between fertilized and unfertilized plots in selected replications. The sites initially chosen are indicated by crosshatching in Figure 9. Due to time limitations, efforts during this initial study period where concentrated on the loblolly plantings in Block IV, Plots 1 and 4. These initial studies correlate well with the observations of Menge as well as correlating extremely well with growth data within these plots as reported by Dinus and Schmidtling (1971).

As part of the ERL forestry applications program, MSS data from 1220 m. over this forest area was obtained under nearly ideal conditions during May, 1974.

As input for a classification to determine the possibility of the subtle difference of signature which might result from the field observed differences of mycorrhizal involvement, the signatures from the pines in each of the two loblolly plots were used to denote this difference. Plot 1 represented a lower incidence of involvement while Plot 4 represented the higher.

The classification shows a mycorrhizal separation and the areas classified as having a high mycorrhizal involvement within Plot 4, correlate with field data from this plot which demonstrates that the areas classified as having a high involvement, were those areas which produced the highest mycorrhizal sporophore counts. The classification results of this study are shown in Figures 10 and 11.

In this paper, the author has demonstrated several techniques one can employ whereby remotely sensed data from various plant associations can be used to obtain information and classification from these plant communities which relate to other aspects of the environment. This inferential approach adds a new dimension to the information obtainable through remote sensing.

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TABLE I. SOME APPLICATIONS OF VEGETATIONAL CLASSIFICATION

(1) MAPPING OF SPECIATION AND SPECIES ASSOCIATIONS.

a) Marsh vegetation inventory and ecological studies.

b) Forest inventory

I) speciation

II) percentage cover or crown closure

c) Agricultural crop acreage inventory

(2) INFERENTIAL CLASSIFICATIONS FROM SPECIES ASSOCIATION CLASSIFICATIONS.

a) Marsh mosquito breeding sites and salinity regimes

b) Environmental parameters xeric vs. mesophytic sites

c) Fusiform risk zones as determined by oak-pine distribution

(3) RECOGNITION OF STRESS AND STRESS RELATED PARAMETERS.

a) Disease, e.g. fusiform rust or bark beetle infestation

b) Mycorrhizal sufficiency or insufficiency

c) Temporary water stress

TABLE II. COMPARISON OF CALCULATED PERCENTAGES OF SIX CLASSES FOUND IN TISHOMINGO STATE PARK AS DERIVED BY PHOTO INTERPRETATION AND SEVERAL MCS CLASSIFICATIONS

[Details in Text]

PERCENTAGE OF CLASSIFIABLE MATERIALS

Interpretation	Rye-Fescue	Pasture	Other Agric.	Pine	Broadleaf Hardwoods	Water	Unclass.	Totals
Photo Interpretation of RC-8 IR	0.02	0.6	0.78	46.2	42.5	5.6	4.3	100.0
Class. I	2.3	0.2	10.62	14.5	53.[illegible]	0.7	18.08	100.0
Class. II	2.2	0.5	8.0	20.0	43.2	4.9	21.2	100.0

LOCATION OF TISHOMINGO STATE PARK

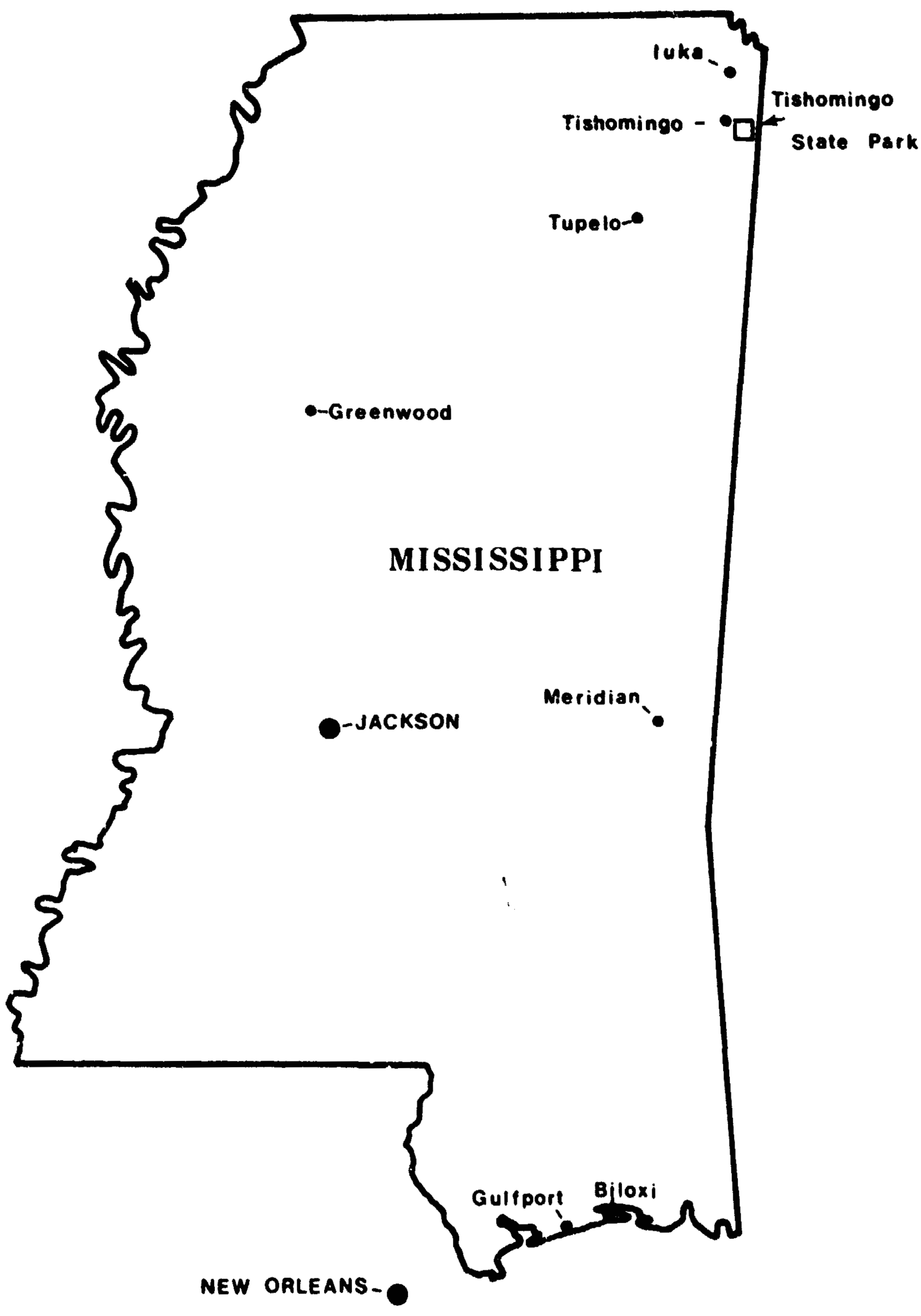
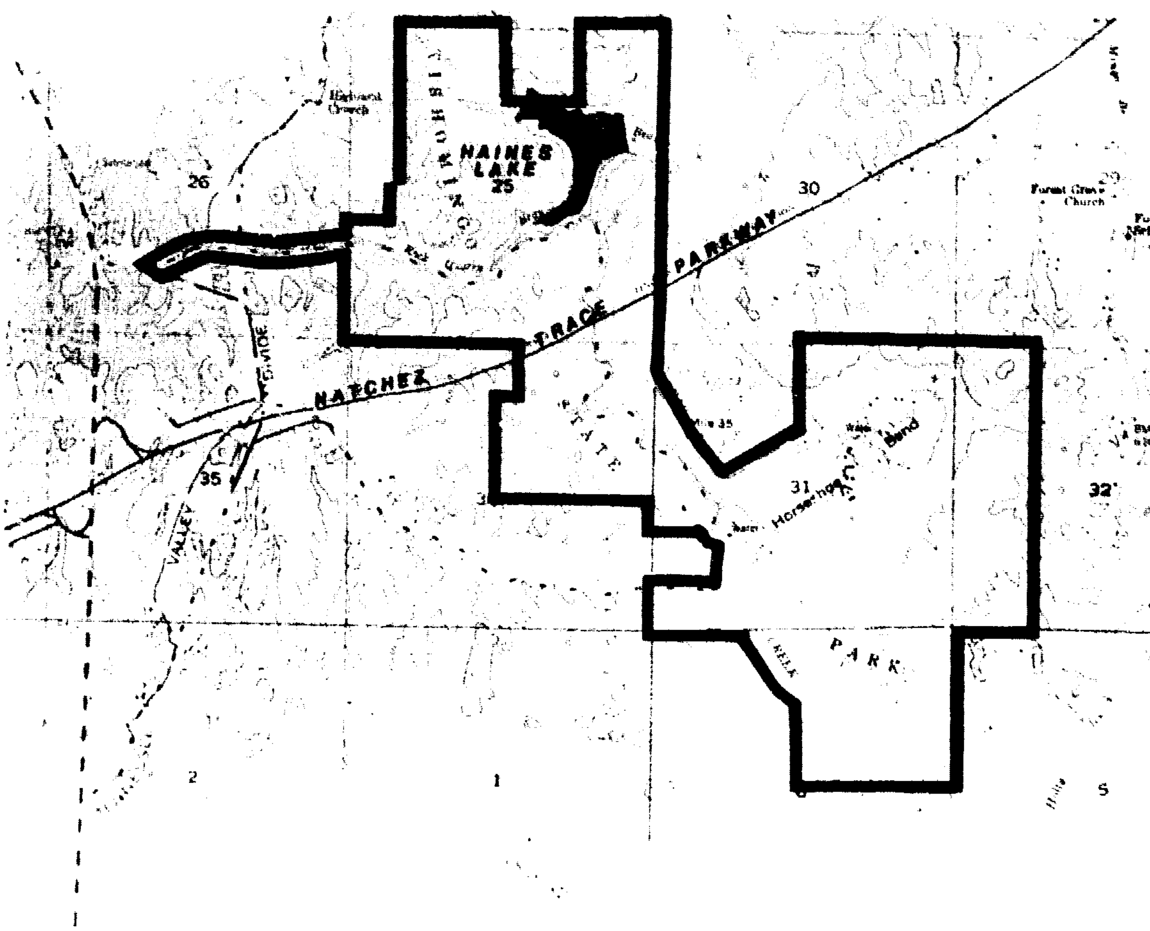


Figure 1



TISHOMINGO STATE PARK

Figure 2

Figure 3. Portion of an RC-8 color infrared photograph taken simultaneously with acquisition of MSS data.

Figure 4.- Preliminary classification of major forest types found in Tishomingo State Park, Mississippi. Red = pine; Green = Broadleaf deciduous; Magenta = Agriculture and some grasslands; Cyan = Rye/ fescue; Blue = Water; White = unclassified.

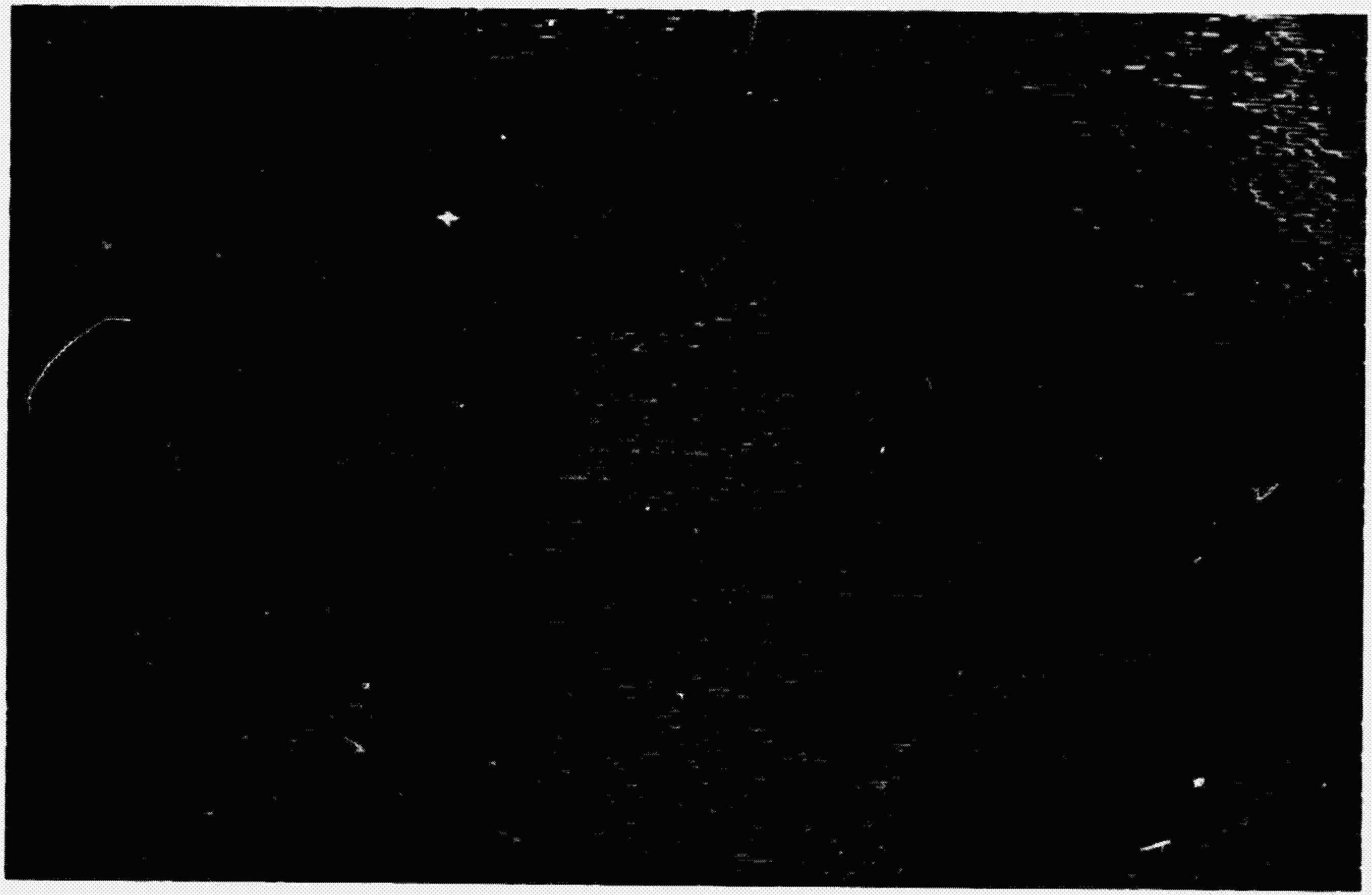
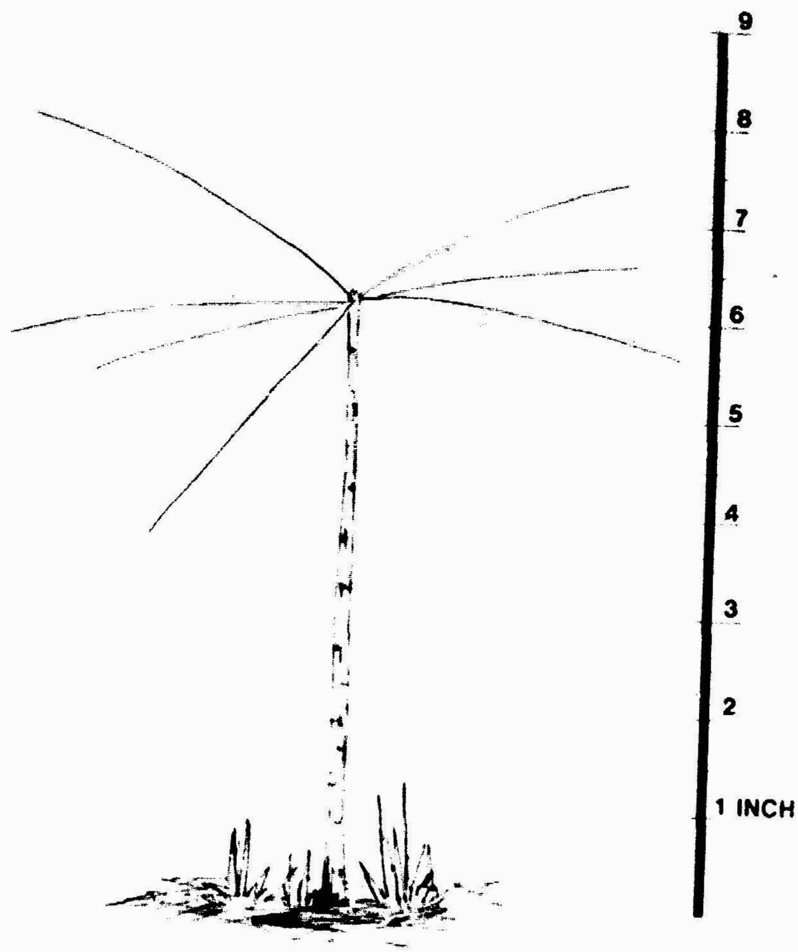
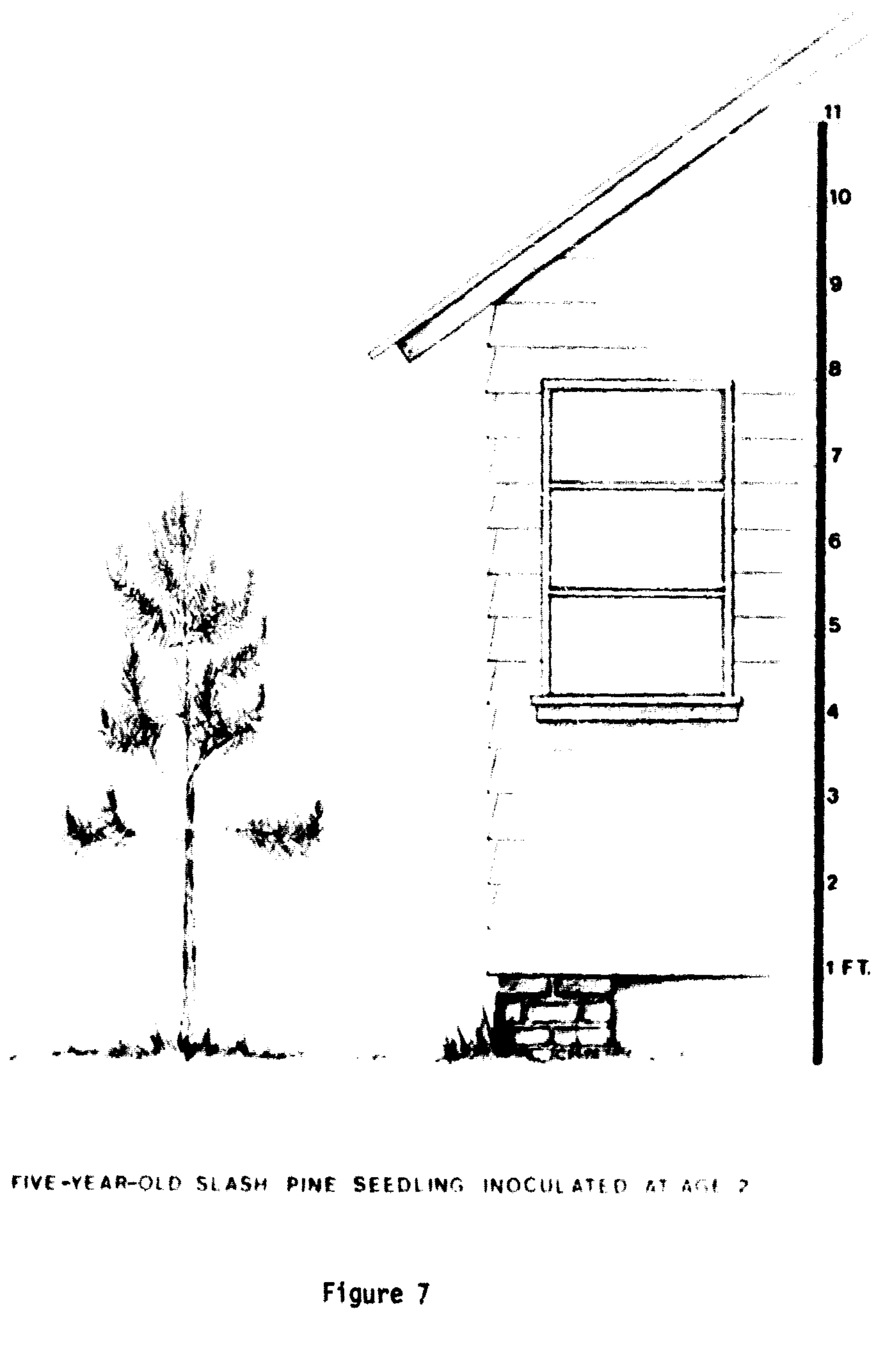


Figure 5.- Preliminary classification of major forest types found adjacent to and in the Fertilization Plot Study Area, Harrison Experimental Forest, De Soto National Forest, Mississippi. Yellow = pine; cyan = Sweetbay, Green = dogwood; orange = oak/black cherry; Gray = unclassified.



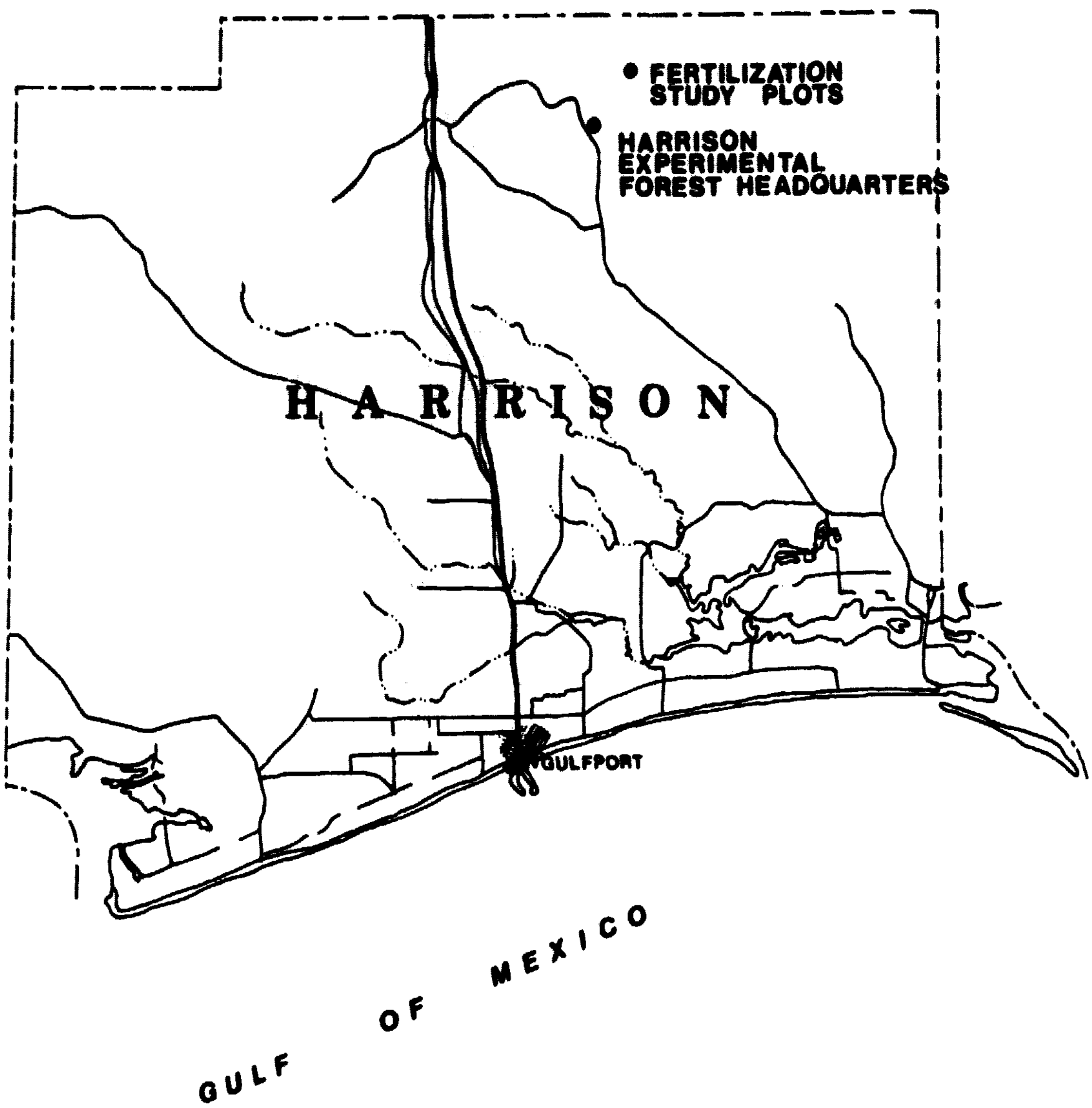
UNINOCULATED SLASH PINE SEEDLING 5 YEARS OLD

Figure 6



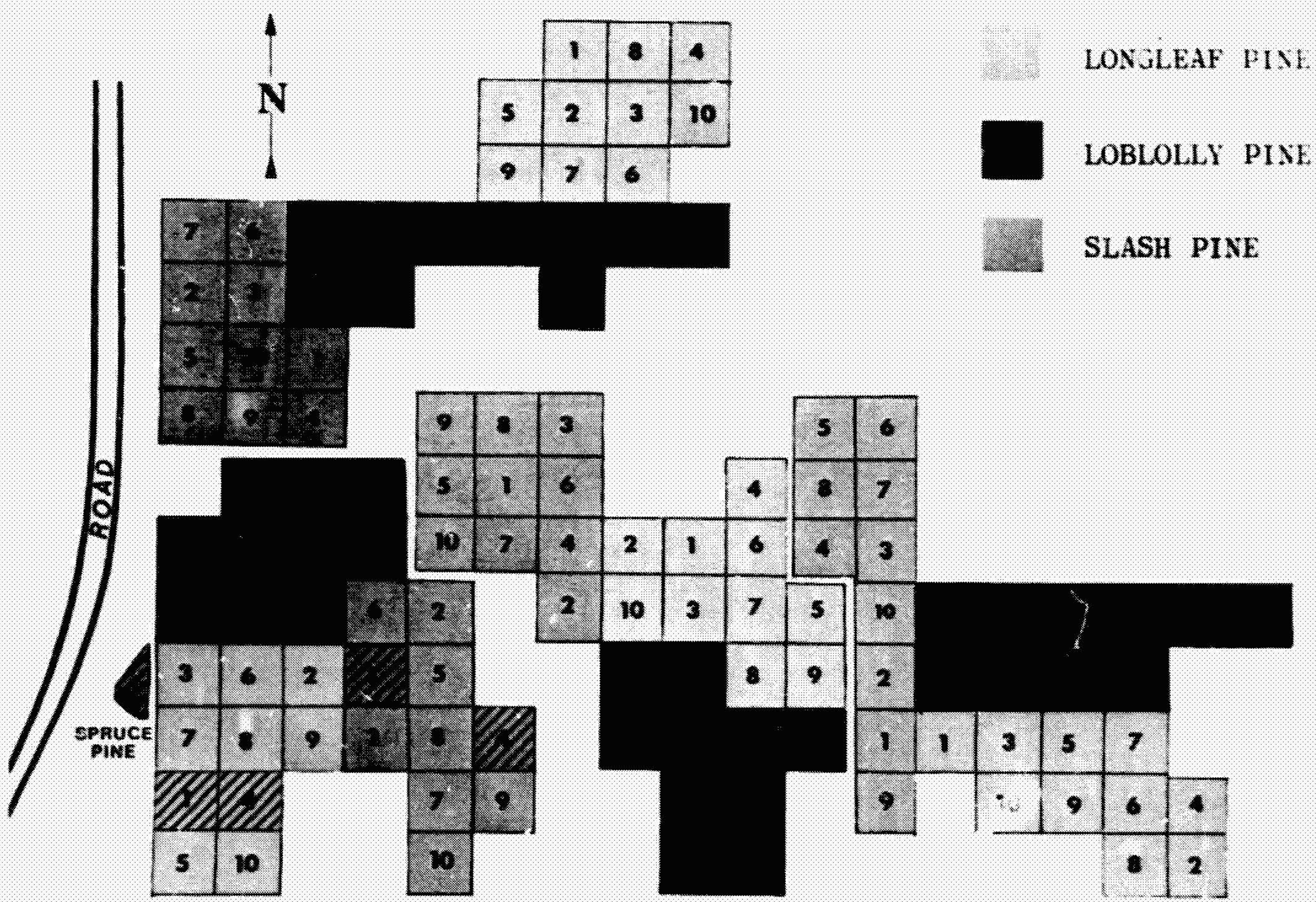
FIVE-YEAR-OLD SLASH PINE SEEDLING INOCULATED AT AGE 2

Figure 7



Harrison Experimental Forest

Figure 8



FERTILIZATION STUDY AREA

HARRISON EXPERIMENTAL FOREST

Figure 9

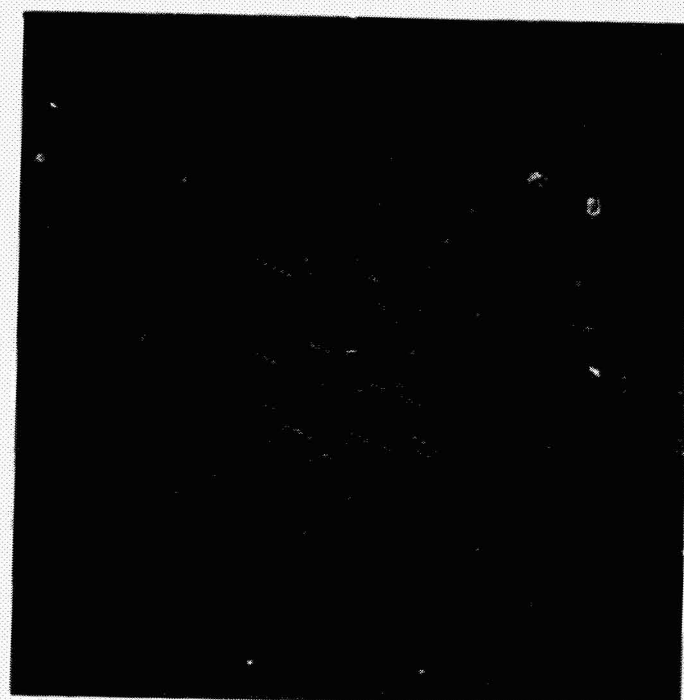


Figure 10.- Loblolly Pine, Plot 1, Block 4, low mycorrhizal involvement. Compare this figure with figure 11.

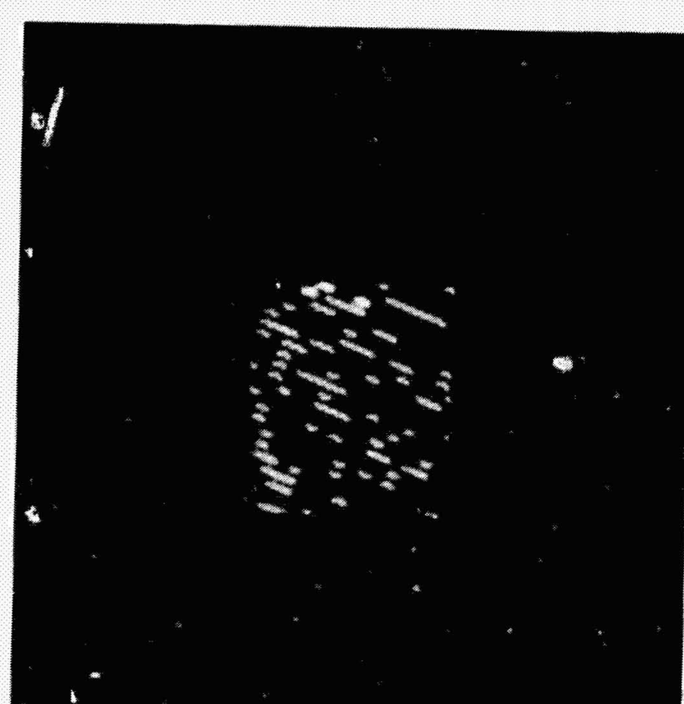


Figure 11.- Loblolly Pine, Block 4, high mycorrhizal involvement. Compare this classification with figure 10, where this same species of pine exists with a lesser degree of mycorrhizal involvement. These two figures demonstrate that the same species of pine exhibit a difference in spectral signature which can be related to the degree of mycorrhizal involvement.